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Johnson

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(54) **NOISE-BASED GAIN ADJUSTMENT AND AMPLITUDE ESTIMATION SYSTEM**

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Related U.S. Application Data

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(51) **Int. Cl.**

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H03G 3/30	(2006.01)
H04L 27/06	(2006.01)
H03F 3/19	(2006.01)

(52) **U.S. Cl.**

CPC ***H03G 3/3036*** (2013.01); ***H03F 3/19*** (2013.01); ***H03G 3/3078*** (2013.01); ***H04L 27/06*** (2013.01); *H03F 2200/294* (2013.01); *H03F 2200/451* (2013.01)

(58) **Field of Classification Search**

CPC . H03G 3/3036; H03F 3/19; H03F 2200/451; H03F 2200/294; H04L 27/06

See application file for complete search history.

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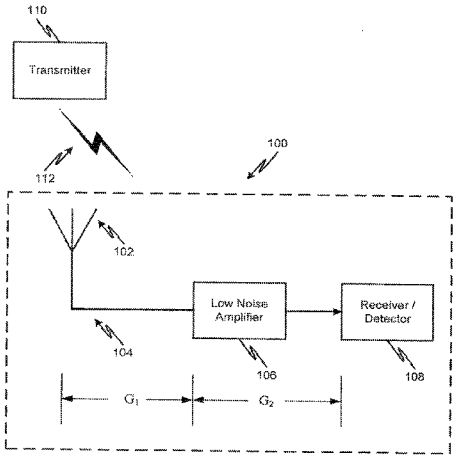
(57) **ABSTRACT**

Methods and systems for amplitude estimation and gain adjustment using noise as a reference are described. An example receiver can include an antenna and a front end amplifier coupled to the antenna. The receiver can also include a detector circuit coupled to the front end amplifier. The receiver can be configured to determine a power of a received signal at the antenna based on a gain of the receiver. The gain of the receiver can be determined based on a noise figure of the front end amplifier and a noise amplitude.

16 Claims, 3 Drawing Sheets



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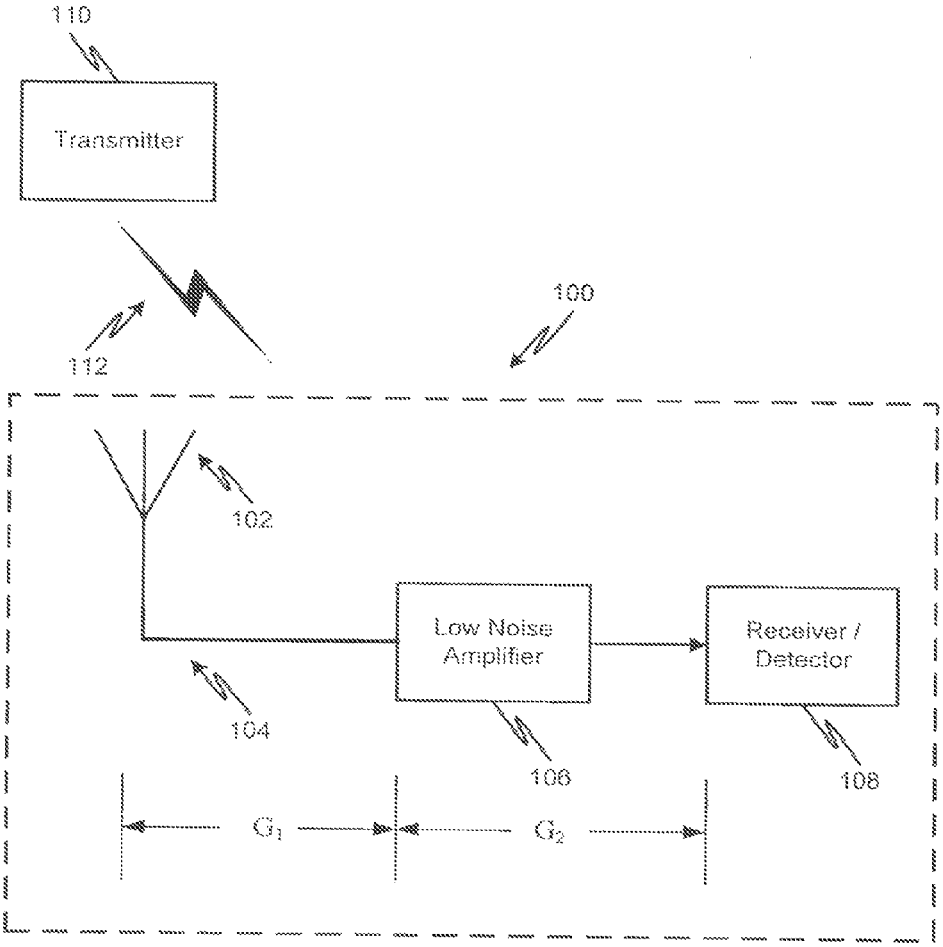
110
Transmitter
112
100
102
Low Noise Amplifier
Receiver / Detector
104
106
108
G_1
G_2

FIG. 1

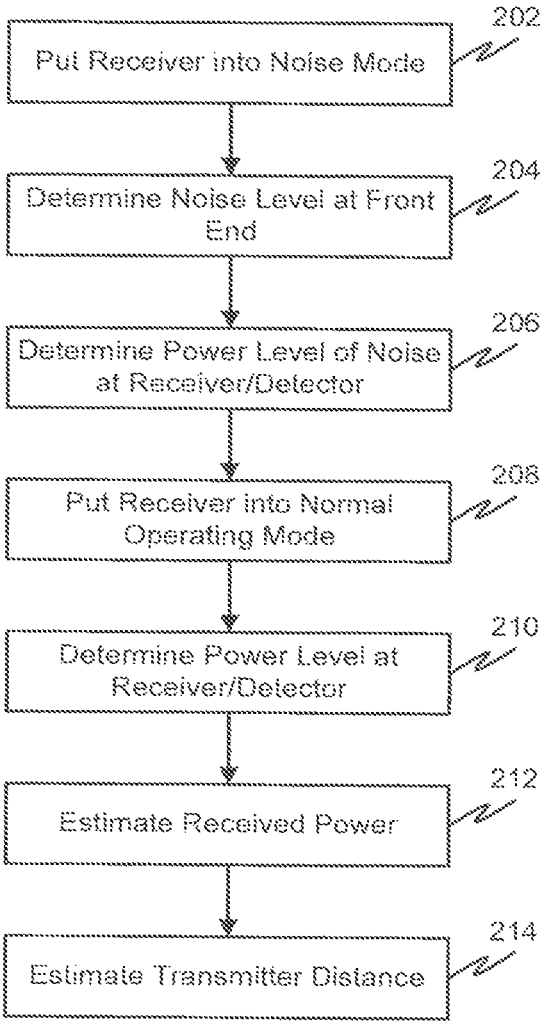
Put Receiver into Noise Mode
202
Determine Noise Level at Front End
204
Determine Power Level of Noise at Receiver/Detector
206
Put Receiver into Normal Operating Mode
208
Determine Power Level at Receiver/Detector
210
Estimate Received Power
212
Estimate Transmitter Distance
214

FIG. 2

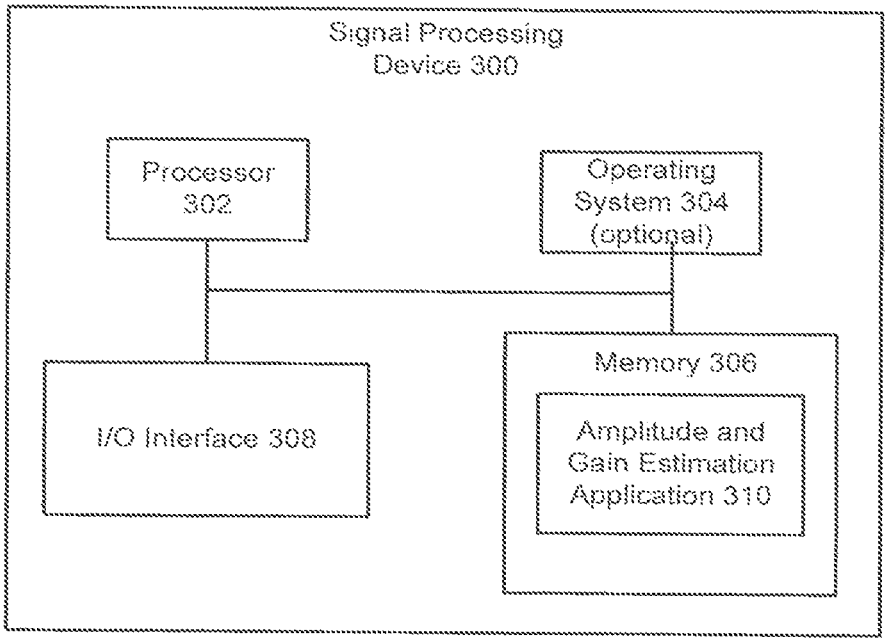
Signal Processing Device 300
Processor 302
Operating System 304 (optional)
I/O Interface 308
Memory 306
Amplitude and Gain Estimation Application 310

FIG. 3

NOISE-BASED GAIN ADJUSTMENT AND AMPLITUDE ESTIMATION SYSTEM

Embodiments relate generally to radio receivers, and more particularly, to methods and systems for signal amplitude estimation and system gain adjustment using noise as a reference.

Some receivers may estimate absolute signal amplitude based on an assumption that for a given configuration (e.g., operating settings), system gain would be constant from system to system. And although variation in gain is known to exist, a nominal gain value is often chosen. Deviations from the nominal value can result in errors when estimating absolute signal amplitude.

Embodiments were conceived in light of the above-mentioned problems and limitations, among other things.

Some embodiments can include a receiver having an antenna, a front end amplifier coupled to the antenna, and a detector circuit coupled to the front, end amplifier. The receiver can be configured to measure signal amplitude at the detector, which can be used to infer received signal amplitude at the antenna based on a gain of the receiver system, based on the following formula:

$$P_D = P_S + G_1 + G_2$$

where P_D is the measured signal amplitude at the detector, P_S is the signal amplitude at the antenna, G_1, is the gain of the antenna and any circuitry up to but not including the front end amplifier and may be known or can be determined by well known techniques, G_2 is the gain of the front end amplifier and subsequent circuitry up to the point of measurement, G_2 may not be precisely known, but can be determined as described below.

The receiver can include a programmable attenuator configured to adjust system gain level, G_2. The system gain level can be selected so as to set observed noise to a predetermined level.

The receiver gain, G_2, can be determined by measuring noise amplitude at the detector in the absence of an input signal based on the formula:

$$P_N = G_2 + NF + 10\log_{10}(k) + 10\log_{10}(T) + 10\log_{10}(B)$$

where P_N is measured noise amplitude at the detector, NF is a system noise figure, k is Boltzmann's constant, T is absolute temperature and B is bandwidth.

The receiver can include a plurality of physical channels. Each channel can also include one or more corresponding programmable attenuators. The receiver can also include a max hold circuit configured to generate a biased estimation of noise power.

Some embodiments can include a method comprising providing a noise estimation for a front end of a receiver, and placing the receiver into noise mode. The method can also include measuring a noise amplitude at a detector subsequent to the receiver front end, and determining a system gain based on the front end noise estimation and the noise amplitude.

The method can further include placing the receiver into a normal receive mode, and receiving a signal at an antenna. The method can include determining a power level of the signal at the detector, and determining an estimated power level of the signal at the antenna based on the system gain.

The method can include estimating a distance of the antenna to a transmitter of the signal based on the estimated power level of the signal at the antenna. The absolute amplitude of the signal can be estimated based on a comparison of the signal amplitude at the detector and estimate of the system gains, G_1 and G_2.

The method can also include comprising adjusting the system gain to maximize instantaneous dynamic range. The method can further include injecting a high-level signal into the receiver so as to saturate the receiver, and include estimating a maximum absolute signal level able to be processed by the receiver.

The method can further include estimating a minimum absolute signal level able to be processed by the receiver based on the noise amplitude.

The method can include comprising removing bias from the noise amplitude measurement based on receiver behavior parameters including one or more of integration time of a max hold circuit, IF bandwidth and video bandwidth. The method can also include setting a programmable thresholding circuit to achieve a predetermined false alarm probability.

Some embodiments can include a system having an antenna and a front end amplifier coupled to the antenna via a cable. The system can also include a detector circuit coupled to the front end amplifier and a programmable attenuator configured to set a system gain level.

The system can be configured to determine a power of a received signal at the antenna based on the system gain level. The system gain level can be determined based on a noise amplitude of the system. Also, the system gain level can be selected so as to set observed noise to a predetermined level.

The receiver can be configured to measure signal amplitude at the detector, which can be used to infer received signal amplitude at the antenna based on a gain of the receiver system, based on the following formula:

$$P_D = P_S + G_1 + G_2$$

where P_D is the measured signal amplitude at the detector, P_S is the signal amplitude at the antenna, G_1 is the gain of the antenna and any circuitry up to but not including the front end amplifier, G_2 is the gain of the front end amplifier and subsequent circuitry up to the point of measurement. G_1 and G_2 may not be precisely known.

The receiver can include a programmable attenuator configured to adjust system gain level, G_2. The system gain level can be selected so as to set observed noise to a predetermined level.

The receiver gain, G_2, can be determined by measuring noise amplitude at the detector in the absence of an input signal based on the formula:

$$P_N = G_2 + NF + 10\log_{10}(k) + 10\log_{10}(T) + 10\log_{10}(B)$$

where P_N is measured noise amplitude at the detector, NF is a system noise figure, k is Boltzmann's constant, T is absolute temperature and B is bandwidth.

The system can also include a plurality of physical channels each having at least one corresponding programmable attenuator. The system can further include a max hold circuit configured to generate a biased estimation of noise power. The system can also include a programmable thresholding circuit configured to be set so as to achieve a predetermined false alarm probability.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of an example receiver system in accordance with at least one embodiment.

FIG. **2** is a flowchart of an example method for amplitude estimation and gain adjustment using noise as a reference in accordance with at least one embodiment.

FIG. **3** is a diagram of an example signal processing system in accordance with at one embodiment.

DETAILED DESCRIPTION

In general, the gain of a receiver can be determined based on noise in the receiver system. The gain can then be used to estimate received signal power at an antenna. Such signal power estimate can be useful for estimating the distance from a transmitter having a known power to a receiver. This kind of estimation may be useful in radar winning receivers, electronic surveillance measures and the like. Embodiments may also be configured for use in audio applications.

FIG. **1** is a diagram of an example multi-channel receiver system **100**. The receiver system **100** includes one or more antennas **102**, cabling **104** to connect each antenna **102** to a front-end amplifier (e.g., a low noise amplifier). The receiver **100** system also includes a receiver/detector circuit **108** coupled to the low noise amplifier **106**. FIG. **1** also shows the sections of the system having gains G_1 and G_2.

In operation, the receiver **100** enters a calibration mode (or noise mode) and determines a system noise factor for the front-end. The noise factor can be based on a theoretical formula or captured and analyzed data. Once the noise factor is determined, the receiver **100** can enter a "live" mode. Once in the "live" mode, the receiver **100** can use a fixed- or variable-level threshold detector (not shown) to identify a signal above noise level.

A transmitter **110** may be at an unknown location and may have a known or estimated transmit power. The transmitter **110** can transmit a signal **112**. The receiver system **100** can receive the signal **112** via antenna **102**. The receiver system **100** can then use an estimate of the received signal **112** power to determine an estimated location (or distance away from the receiver **100**) of the transmitter **110**. The process of determining system noise is described below in connection with FIG. **2**.

In some embodiments, the gain can be manually and/or automatically recomputed as described herein, in response to a change in a system configuration parameter such as gain, bandwidth, frequency tuning and/or the like.

FIG. **2** is a flowchart of an example method for amplitude estimation and gain adjustment using noise as a reference in accordance with at least one embodiment. Processing begins at **202**, where a receiver is put into noise mode. Noise mode can include switching off an antenna so that a receiver is receiving essentially a noise signal generated by the circuitry. Processing continues to **204**.

At **204**, a noise level (or amplitude) for the receiver front end is determined. The noise level of the front end can be based on a theoretical estimate such as N=kTB, where N equals noise, k is Boltzmann's constant, T is absolute temperature and B is bandwidth. The noise level from die front end can also be provided, at least in part, by factory data. Processing continues to **206**.

At **206**, a power level (or amplitude) of the system noise signal is measured at the receiver/detector (e.g., **108**). The receiver can include a programmable attenuator configured to adjust system gain level, G_2. The system gain level can be selected so as to set observed noise to a predetermined level. The receiver gain, G_2, can be determined by measuring noise amplitude at the defector in the absence of an input signal based on the formula:

$$P_N = G_2 + NF + 10\log_{10}(k) + 10\log_{10}(T) + 10\log_{10}(B)$$

where P_N is measured noise amplitude at the detector, NF is a system noise figure, k is Boltzmann's constant, T is absolute temperature and B is bandwidth. Processing continues to **208**.

At **208**, the receiver is placed info operating mode (e.g., the antenna is opened up). Processing continues to **210**.

At **210**, a power level (or signal amplitude) is determined at the receiver/detector. Processing continues to **212**.

At **212**, the power or amplitude of the signal received at the antenna is estimated using the gain computed in **206**, which includes terms for noise and bandwidth. Processing continues to **214**.

Regarding steps **210** and **212**, as discussed above, the receiver can be configured to measure signal amplitude at the detector, which can be used to infer received signal amplitude at the antenna based on a gain of the receiver system, based on the following formula:

$$P_D = P_S + G_1 + G_2$$

where P_D is the measured signal amplitude at the detector, P_S is the signal amplitude at the antenna, G_1 is the gain of the antenna and any circuitry op to but not including the front end amplifier, G_2 is the gain of the front end amplifier and subsequent circuitry up to the point of measurement. G_1 and G_2 may not be precisely known.

At **214**, the distance from the receiver antenna to a transmitter is estimated based on the received power.

It will be appreciated that **202-214** may be repealed in whole or in part in order to accomplish a contemplated amplitude estimation and/or gain adjustment task using noise as a reference.

FIG. **3** is an example signal processing system **300** in accordance with at least one embodiment. The signal processing system **300** includes a processor **302**, operating system **304** (optional), memory **306** and I/O interface **308**. The memory **306** can include an amplitude and gain estimation application **310**.

In operation, the processor **302** may execute the application **310** stored in the memory **306**. The application **310** can include software instructions that, when executed by the processor, cause the processor to perform operations for signal processing in accordance with the present disclosure (e.g., performing one or more of steps **202-214** described above).

The application program **312** can operate in conjunction with the operating system **304**.

It will be appreciated that the modules, processes, systems, and sections described above can be implemented in hardware, hardware programmed by software, software instructions stared on a nontransitory computer readable medium or a combination of the above. A system as described above, for example, can include a processor configured to execute a sequence of programmed instructions stored on a nontransitory computer readable medium. For example, the processor can include, but not be limited to, a signal processor, a programmable receiver, a personal computer or workstation or other such computing system that includes a processor, microprocessor, microcontroller device, or is comprised of control logic including integrated circuits such as, for example, an Application Specific integrated Circuit (ASIC). The instructions can be compiled from source code instructions provided in accordance wife a programming language such as Java, C, C++C#.net, assembly or the like. The instructions can also comprise code and data objects provided in accordance with, for example, the Visual Basic™ language, or another structured or object-oriented programming language. The sequence of

programmed instructions, or programmable logic device configuration software, and data associated therewith can be stored in a nontransitory computer-readable medium such as a computer memory or storage device which may be any suitable memory apparatus, such as, but not limited to ROM, PROM, EEPROM, RAM, flash memory, disk drive and the like.

Furthermore, the modules, processes systems, and sections can be implemented as a single processor or as a distributed processor. Further, it should be appreciated that the steps mentioned above may be performed on a single or distributed processor (single and/or multi-color cloud computing system). Also, the processes, system components, modules, and sub-modules described in the various figures of and for embodiments above may be distributed across multiple computers or systems or may be co-located in a single processor or system. Example structural embodiment alternatives suitable for implementing the modules, sections, systems, means, or processes described herein are provided below.

The modules, processors or systems described above can be implemented as a programmed general purpose computer, an electronic device programmed with microcode, a hard-wired analog logic circuit, software stored on a computer-readable medium or signal, an optical computing device, a networked system of electronic and/or optical devices, a special purpose computing device, an integrated circuit device, a semiconductor chip, and/or a software module or object stored on a computer-readable medium or signal, for example.

Embodiments of the method and system (or their sub components or modules), may be implemented on a general-purpose computer, a special-purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element, an ASIC or other integrated circuit, a digital signal processor, a hardwired electronic or logic circuit such as a discrete element circuit, a programmed logic circuit such as a PLD, PLA, FPGA, PAL, or the like. In general, any processor capable of implementing the functions or steps described herein can be used to implement embodiments of the method, system, or a computer program product (software program stored on a nontransitory computer readable medium).

Furthermore, embodiments of the disclosed method, system, and computer program product (or software instructions, stored on a nontransitory computer readable medium) may be readily implemented, fully or partially, in software using, for example, object or object-oriented software development environments that provide portable source code that can be used on a variety of computer platforms. Alternatively, embodiments of the disclosed method, system, and computer program product can be implemented partially or fully in hardware using, for example, standard logic circuits or a VLSI design. Other hardware or software can be used to implement embodiments depending on the speed and/or efficiency requirements of the systems, the particular function, and/or particular software or hardware system, microprocessor, or microcomputer being utilized. Embodiments of the method, system, and computer program product can be implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the function description provided herein and with a general basic knowledge of the electrical engineering and signal processing arts.

Moreover, embodiments of the disclosed method, system, and computer readable media (or computer program product) can be implemented in software executed on a programmed general purpose computer, a special purpose computer, a microprocessor, or the like.

It is, therefore, apparent that there is provided, in accordance with the various embodiments disclosed herein, methods, systems and computer readable media for amplitude estimation and gain adjustment using noise as a reference.

While the disclosed subject matter has been described in conjunction with a number of embodiments, it is evident that many alternatives, modifications and variations would be, or are, apparent to those of ordinary skill in the applicable arts. Accordingly, Applicant intends to embrace all such alternatives, modifications, equivalents and variations that are within the spirit and scope of the disclosed subject matter.

What is claimed is:

1. A receiver comprising:
an antenna; and
a detector circuit coupled to the antenna,
wherein the receiver is configured to determine a power of a received signal at the antenna based on a gain of the receiver, and
wherein the gain of the receiver is determined based on a predetermined noise figure of a front end amplifier and a noise amplitude measured by the detector circuit.

2. The receiver of claim **1**, further comprising a programmable attenuator configured to set system gain level.

3. The receiver of claim **2**, wherein the system gain level is selected based on a predetermined noise level.

4. The receiver of claim **1**, wherein the gain of the receiver is determined by measuring the noise amplitude at the detector in an absence of an input signal.

5. The receiver of claim **4**, wherein the gain of the receiver is determined based on the measured noise amplitude at the detector, the system noise figure, Boltzmann's constant, an absolute temperature, and a bandwidth of the receiver.

6. The receiver of claim **1**, further comprising a plurality of physical channels each having at least one corresponding programmable attenuator.

7. The receiver of claim **1**, further comprising a max hold circuit configured to generate a biased estimation of noise power.

8. The receiver of claim **1**, wherein the receiver is configured to estimate a distance of the antenna to a transmitter of the received signal based on the determined power of the received signal.

9. A system comprising:
an antenna;
a detector circuit coupled to the antenna; and
a programmable attenuator configured to set a system gain level,
wherein the system is configured to determine a power of a received signal at the antenna based on the system gain level, and
wherein the system gain level is determined based on a noise amplitude of the system measured by the detector circuit and a predetermined system noise figure.

10. The system of claim **9**, wherein the system gain level is selected based on a predetermined noise level.

11. The system of claim **9**, wherein the system gain level is determined by measuring the noise amplitude at the detector in an absence of an input signal.

12. The system of claim **11**, wherein the system gain level is based on the measured noise amplitude at the detector, the system noise figure, Boltzmann's constant, absolute temperature, and bandwidth.

13. The system of claim 9, further comprising a plurality of physical channels each having at least one corresponding programmable attenuator.

14. The system of claim 9, further comprising a max hold circuit configured to generate a biased estimation of noise power.

15. The system of claim 9, further comprising a programmable thresholding circuit configured to be set so as to achieve a predetermined false alarm probability.

16. The system of claim 9, wherein the system is configured to estimate a distance of the antenna to a transmitter of the received signal based on the power of the received signal.

* * * * *